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A theoretical framework to ISO 45001:2018 OHS management system: the improvement of its application steps by quality circles

ISO 45001:2018 İSG yönetim sisteminin teorik çerçevesi: uygulama adımlarının kalite çemberleri tarafından iyileştirilmesi

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A Theoretical Framework to ISO 45001:2018 OHS Management System: The Improvement of Its Application Steps by Quality Circles

Highlights

- *ISO 45001:2018 and quality circles are examined*
- *A new process was proposed to ensure critical success factors.*
- *Spherical fuzzy sets and the AHP method were used in the analysis.*

Graphical Abstract

ISO 45001:2018 standard and quality circles were evaluated together and a new process was proposed.

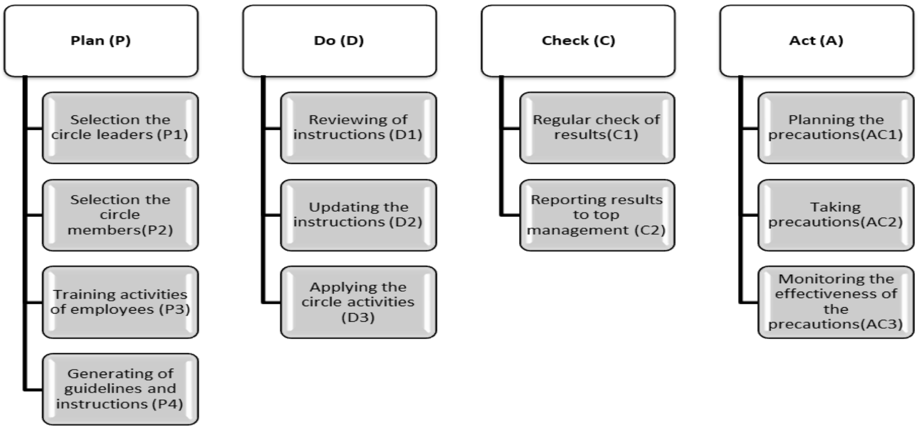

Figure. The determined key points of the proposed approach

Aim

To propose a systematic and strategic improvement in managament and OHS applications by ISO 45001:2018 quality circles approaches.

Design & Methodology

The spherical fuzzy sets and AHP were used to calculate the relative importance weights of the determined critical points to ensure the successfull integration.

Originality

The main contribution is to transform ISO 45001:2018's application phases into a holistic problem-solving approach using quality circles and to determine which process steps to prioritize.

Findings

The control activity and feedback mechanism is the most critical roles.

Conclusion

This study is a first in the literature in many respects, with the expansion of ISO 45001:2018, the proposal of a new process based on this, and the calculation of the critical points of this process, and highligted managerial application aspects.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

A Theoretical Framework to ISO 45001:2018 OHS Management System: The Improvement of Its Application Steps by Quality Circles

Araştırma Makalesi / Research Article

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ABSTRACT

ISO 45001:2018 Occupational Health and Safety Management Systems operate their processes by placing employee participation at the center. A systematic and strategic improvement can be achieved for ISO 45001:2018 through the quality circles approach by disseminating managerial activities throughout the enterprise and integrating them into the implementation steps. In this study, a new process proposal was developed to improve and facilitate the implementation steps of ISO 45001:2018, ensuring this integration. The critical success factors of the proposed process were identified. The relative importance weights of these critical points were calculated using the fuzzy extension of the Analytic Hierarchy Process. Planning and regular result-checking were determined to be the most important main and sub-key factors, respectively. The main contribution of this paper to the literature is the transformation of ISO 45001:2018's unique application phases into a holistic problem-solving approach using quality circles. As a result, both worker participation and the safety culture that ISO 45001:2018 aims to promote have successfully permeated the organization. The secondary contribution of this study is the identification of which process steps should be prioritized to achieve success quickly and securely, using an analytical approach.

Keywords: ISO 45001:2018, sustainability, quality circles, strategic management, spherical fuzzy AHP.

ISO 45001:2018 İSG Yönetim Sisteminin Teorik Çerçevesi: Uygulama Adımlarının Kalite Çemberleri Tarafından İyileştirilmesi

ÖZ

ISO 45001:2018 İş Sağlığı ve Güvenliği yönetim sistemleri süreçlerini çalışanların katılımını merkeze alarak yürütmektedir. Yönetimsel faaliyetlerin işletme geneline yayılması ve uygulama adımlarına entegre edilmesiyle kalite çemberleri yaklaşımı kullanılarak ISO 45001:2018 için sistematik ve stratejik bir iyileştirme sağlanabilir. Bu çalışmada ISO 45001:2018 uygulama adımlarını iyileştirmek ve kolaylaştırmak amacıyla bu entegrasyonu sağlayacak yeni bir süreç önerisi yapılmış ve kritik başarı faktörleri belirlenmiştir. Belirlenen bu kritik faktörlerin göreli önem ağırlıkları Analitik Hiyerarşi Sürecinin bulanık genişlemesi kullanılarak hesaplanmıştır. Sonuçların planlanması ve düzenli olarak kontrol edilmesi sırasıyla en önemli ana ve alt anahtar faktörler olarak belirlenmiştir. Bu makalenin literatüre yaptığı temel katkı, ISO 45001:2018'in benzersiz uygulama aşamalarını kalite çemberlerini kullanarak bütünsel bir problem çözme yaklaşımına dönüştürmektir. Sonuç olarak, hem çalışanların katılımı hem de ISO 45001:2018'in teşvik etmeyi amaçladığı güvenlik kültürü, bu bakış açısıyla kuruluş geneline nüfuz edebilecektir. Bu çalışmanın ikincil katkısı ise başarıya hızlı ve güvenli bir şekilde ulaşmak için hangi süreç adımlarına öncelik verilmesi gerektiğinin belirlenmesi ve bunun analitik bir yaklaşımla yapılmasıdır.

Anahtar Kelimeler: ISO 45001:2018, sürdürülebilirlik, kalite çemberleri, stratejik yönetim, küresel bulanık AHP.

1. INTRODUCTION

It is a well-known truth that until a sustainable management system is followed, it is hard to achieve holistic success in nearly all processes. Especially in work processes that include labor-intensive duties, the well-being of human resources in terms of Occupational Health and Safety (OHS) and motivational aspects contributes to employee resilience and the sustainability of the business process [1–4]. Thus, the role of human factors in the sustainability of business processes is an undeniable truth [3].

Despite the success of advanced measurement methods and technology, OHS activities mainly focus on controlling individual behaviors and physical risks from the environment or job design, leading to positive outcomes but failing to achieve organization-wide integration within the management philosophy [5]. In terms of OHS and ergonomics that handle the well-being of human factors as the main issue in business, sustainability issues need also be considered so that it can continue to protect humans. Since the fundamentals of occupational health and safety science are grounded on

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providing a safe, convenient, and bearable working environment in regard to ergonomics philosophy [4], in terms of protecting employees from work accidents and preventing occupational diseases, OHS activities contribute to the sustainability of human resources. However, OHS management approaches need to be also sustainable so that businesses can achieve their final goals. At this point, the implementation of standardized management systems—particularly those aligned with internationally recognized frameworks such as ISO—gains significant importance in establishing and maintaining sustainability within organizations. Specifically, ISO 45001:2018, which focuses on occupational health and safety management, plays a crucial role in fostering continuous improvement and embedding sustainable practices across all levels of the enterprise [6]. This standard not only provides a structured approach to risk reduction and regulatory compliance but also integrates sustainability as a core component of organizational strategy. In management system approaches like ISO 45001:2018, sustainability is not treated as an isolated goal but rather as an integral element that influences the effectiveness and long-term success of the entire system. Moreover, ensuring the sustainability of such processes requires active employee involvement and strong leadership commitment. Both factors are essential in cultivating a culture of safety, accountability, and continuous enhancement, which collectively drive the sustainable performance of the organization.ISO 45001:2018, unlike OHSAS 18001, has placed employee participation and leadership at the center of the Plan-Do-Check-Act (PDCA) cycle. With ISO 45001:2018, an OHS management system has been developed that operates with a common language shared by all ISO standards. In addition to this, it is an improved version that addresses the disadvantages of OHSAS 18001.

Going back to employee participation, according to most researchers, it is one of the critical success factors of OHS management systems [7]. Thus, by applying the PDCA cycle to the OHS management system, managers also need to consider employee participation to ensure sustainability. From this point of view, employee participation becomes more important in processes where changes in the way employees perform their work or the measures to be taken at work are planned and implemented—and OHS processes are exactly such processes.

Karanikas, Weber, Bruschi, and Brown [8] investigated the systems thinking dimensions embedded within the ISO 45001:2018 OHS management system. In their study, they identified eight key systems thinking principles that align with the structure and intent of ISO 45001:2018. One of their main findings emphasizes that OHS management systems based on the Plan-Do-Check-Act (PDCA) cycle inherently promote the distribution of responsibility across both system-wide and localized levels of performance. This highlights the ongoing need for a structured and systemic approach to sustainability—one that integrates systems thinking with the PDCA methodology of ISO 45001:2018. Although employee participation and sustainability are widely recognized as essential components in theory, ensuring their effective implementation in practice remains a challenge. This gap between theory and practice is evident in the continued occurrence of workplace accidents and occupational diseases, despite the formal adoption of OHS management systems. These outcomes underline the importance of not only implementing such systems but also fostering genuine engagement and accountability at all organizational levels.

On the other hand, the quality management approach can be applied to safety management practices to improve the effectiveness of safety management [9, 10]. If quality circles, which are an effective tool of Total Quality Management, can be used effectively in any management system—as in TQM—the human participation parameter in the OHS management system can be achieved. Moreover, if quality circles can be used in the OHS management system, they can contribute to the creation of an OHS culture in enterprises. In this case, just like the use of quality circles in solving ergonomic problems, integrating the quality circles approach into the PDCA cycle of OHS management systems will create many advantages, such as the formation of a safety culture, employee participation, and the generalization of OHS awareness. Integrated OHS management is known to reduce occupational accidents when combined with ergonomic practices. It is also known that the P and D steps in the PDCA cycle, under the authority of top management, are effective for the success of ergonomic practices [11].

It is hoped that these advantageous situations will correspond to fewer occupational accidents and occupational diseases in terms of strategic OHS management. The purpose of quality circles is to spread the improvements made and to affect the entire enterprise. Obviously, the benefit of this situation goes beyond hope, and it has been revealed that the application of quality circles—at least in an ergonomic sense—provides a wide variety of contributions to the business. It has been suggested by Lee [12] that quality circle approaches should be integrated into the application steps of ergonomic principles to adapt ergonomic approaches to the overall enterprise. It has been stated that this change can be achieved through a system consisting of 8 steps, which is expanded with quality circles. The 8-step structure proposed by Lee was modernized by Adem, Yılmaz Kaya, and Dağdeviren [13], and the commitment of top management and employee participation was emphasized as an important part of this process.

Processes integrated with TQM approaches can be used to extend participatory ergonomics and macroergonomics approaches to the entire enterprise. It may be a rational approach to use quality circle approaches to make basic ergonomics studies sustainable and to include regular control mechanisms in the process. From this point of view, quality circles can be used to facilitate the applicability of ISO 45001:2018—an OHS management system that was developed based on the PDCA cycle and includes the participation and leadership of employees at the core of the cycle—and to spread ISO 45001:2018, which is integrated with other management systems, throughout the enterprise. Moreover, in a management system where employee participation is positioned as a foundational element of the implementation process, integrating a system proposal based on quality circles can serve as a strategic approach to enhance and strengthen the overall framework. Building on this perspective, the primary objective of the present study is to develop a process model that integrates the implementation steps of ISO 45001:2018 with the principles of Total Quality Management (TQM) and the practical benefits of quality circles. In addition to this primary aim, a secondary objective is to identify and analyze the critical success factors that influence the effectiveness of such an integrated system. Organizations that transitioned from OHSAS 18001 to ISO 45001:2018 underwent a significant change process. Although they were familiar with the structure of OHSAS 18001, ISO 45001:2018 introduces new concepts and requirements that necessitate organizational adaptation [7, 14]. This new standard offers substantial opportunities to transform workplace perceptions of occupational health and safety. However, the potential benefits of ISO 45001:2018 may be diminished if excessive time and resources are allocated to unnecessary bureaucratic tasks [7]. To address this challenge, the guidelines proposed in this study offer a simplified and analytical framework that can facilitate practical implementation. This study proposes a novel process framework that unifies quality circles with ISO 45001:2018, offering a fresh perspective on ISO-based management systems. A key contribution of the research lies in the identification of critical points within the proposed process and the evaluation of their relative importance, which further enhances the study's originality and practical value. Applying the structured processes suggested herein can serve as a strategic advantage, particularly for enterprises navigating the complexities of a new system, by supporting the diffusion of the management system throughout the organization in an efficient and effective manner.

The anticipated outcome of this study is to provide a set of recommendations aimed at enhancing the overall success of processes carried out within the OHS management system. This sequence of proposals is intended to offer a novel perspective on ISO-based management systems by simplifying the implementation steps of ISO 45001:2018 and integrating them with quality circles—an approach whose effectiveness has been validated over time. Furthermore, the study contributes by presenting the proposed process through a visual flow diagram and offering an implementation guide tailored for enterprises, underpinned by the identification of critical success factors. The adoption of the ISO 45001:2018-based model developed within the scope of this research is expected to be particularly advantageous for organizations seeking to strategically advance sustainable OHS management practices.

To accomplish these aims, the rest of this paper is structured as follows: Section 2 provides information on how to improve ISO 45001:2018 with quality circles. Section 3 presents the calculation process of the critical success factors of ISO 45001:2018 enhanced with quality circles. Section 4 focuses on determining and weighing the key points of the proposed approach. Section 5 discusses the results and provides an analysis of the study. Section 6 presents the concluding remarks.

2. QUALITY CIRCLES WITH ISO 45001:2018

We first encounter a mention of quality circles in the book The Japanese Approach to Product Quality, in the chapter Quality Control in Japan, where the concept was introduced by Kaoru Ishikawa in 1984. This chapter highlights that one of the most important features of company-wide quality control in Japan is the quality circle movement, which began in 1962 [15]. When Total Quality Management first emerged, it was primarily used to increase efficiency and reduce errors in production processes. However, over time, it has evolved to meet the needs of a changing world. In addition to the production sector, it has been adapted to industries where knowledge, innovation, and service are at the forefront, thus expanding its field of application. [16].

There are two aims of quality circles. The first of these aims is to ensure the participation of top management in the processes, and to make this participation sustainable [17]. When this approach is evaluated together with strategic OHS management, it can be said that they are aligned, as both seek the participation of top management. Moreover, quality circles can be a tool that facilitates the participation of managers in processes within systems like ISO 45001:2018.

The second aim of quality circles is to address employees' needs [17]. This aim also aligns with the objective of strategic OHS management in terms of developing an OHS culture and ensuring the well-being of employees in the workplace. Even just considering the direction of these two aims, the reason for applying quality circles to OHS management systems becomes clear. Particularly, given that quality circles are directly related to job satisfaction and employee motivation [18, 19], the basic aims of OHS and the aims of quality circles can be considered complementary and mutually supportive.

In literature, there are limited studies that handles quality circles with ISO standards. Moreover, the literature reflects a diverse range of perspectives on standards and quality circles. For example, Ahsan and Ullah [20] aimed to compare the organizational performance of firms in terms of total quality management between ISO 9001:2015 certified and non-certified firms in Bangladesh. In this comparison, the role of quality circles is also emphasized. However, their study is not focused on OHS or ISO 45001 and does not address OHS performance. It discusses the overall organizational performance of the firms in terms of having ISO 9001 certificate.

Demilly et al. [21] conducted a survey-based study to examine the impact of total quality management on workplace well-being and empowering leadership, as well as to explore the relationship between them. According to their findings, the presence of quality management in the workplace enhances both organizational performance and employee well-being. Considering that the main purpose of ISO 45001 is to enhance employee well-being in the workplace through occupational health and safety, the assessment that the processes proposed in the current study—including the expansion of the ISO 45001 standard within the framework of quality circles—will positively contribute to the OHS performance of enterprises is further reinforced.

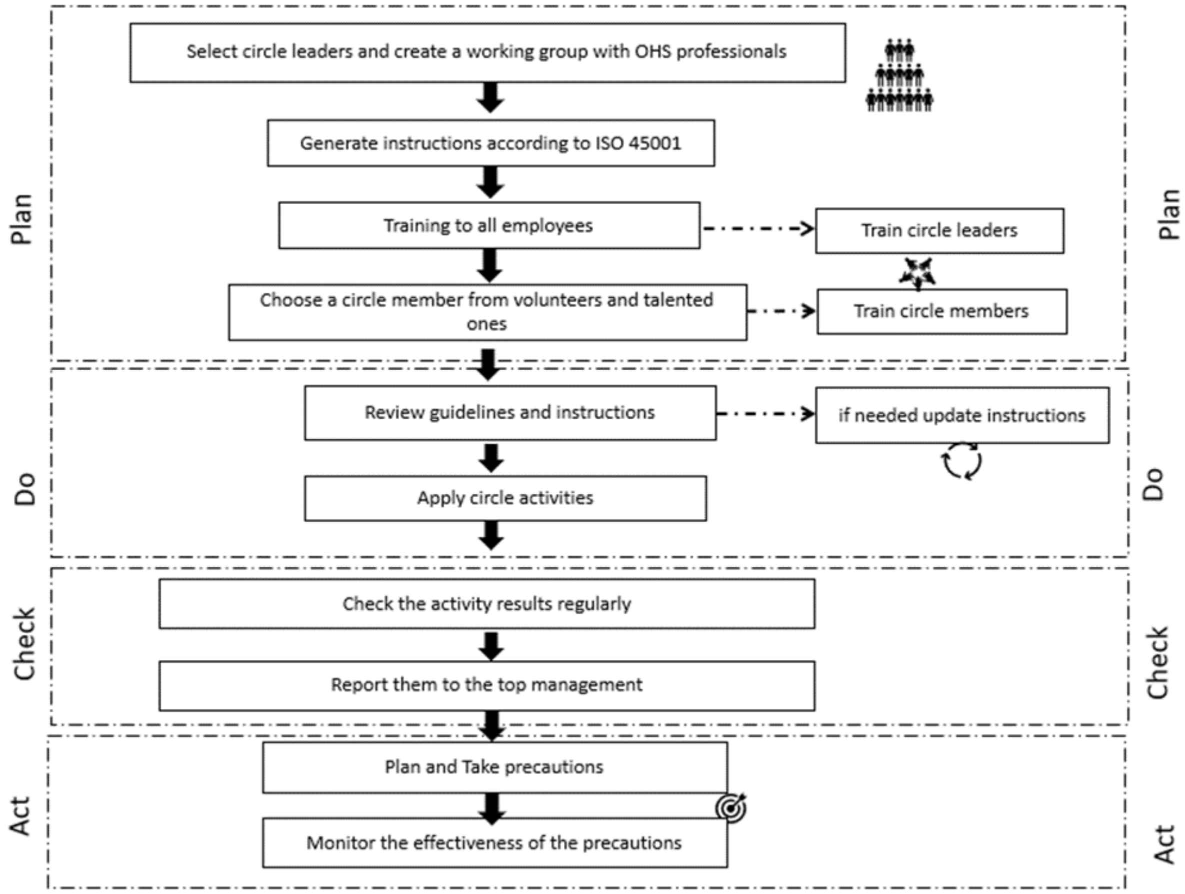

Figure 1. The illustration of the extension of ISO PDCA cycle with quality circles

Moreover, Krishnasamy, Rahman, and Mohamed [22] investigated whether ISO 45001 certification has an impact on occupational accidents in the construction industry. Their findings revealed that accident rates were lower in ISO 45001-certified companies, indicating that the certification positively influences occupational safety performance. The positive effect of ISO 45001 in reducing OHS accidents can be further enhanced by the systematic approach that quality circles bring to management processes.

On the other hand, Öztuna [23] suggested that quality circles could be utilized as a problem-solving technique within participatory ergonomics. However, he did not propose a specific process for their application. Liu, Liu, Li, and Wen [24] studied the barriers to the effective application of OHSMS. They identified 16 barriers and then analyzed these barriers using DEMATEL-ISM, one of the MCDM techniques. According to their results, lack of employee awareness, safety culture, and participation are among the most important barriers to the effective application of ISO 45001:2018 in companies. In particular, employee participation and awareness provide a significant advantage in OHSMS. One of the objectives of the current study is to facilitate the integration of employee participation into the process with the proposed system and to raise employee awareness by spreading the OHS culture throughout the organization. Skład [7] studied the effect of OHS management systems by utilizing fuzzy cognitive maps, identifying 15 processes, including organizational roles, monitoring, and performance evaluation. Afterward, Skład [7] analyzed these processes using fuzzy cognitive maps. According to the results, leadership was found to have the greatest contribution to the OHS management system.

The function of quality circles in companies can be explained as follows: focusing on solutions to various problems, identifying the root causes of these problems, and planning the solution procedures. A circle team needs to include a circle leader, circle members, a guide, and a functioning committee [15]. Since being a member of a circle and performing duties are entirely voluntary, it is important to establish a well-functioning circle to achieve successful circle activities. The integration of such a process, which is heavily based on systematic problem-solution approaches, into the ISO 45001:2018 OHS management system is expected to improve the ability to determine the root causes of work accidents and occupational diseases.

When the literature is reviewed as a whole, it becomes evident that quality circles and standards such as ISO 45001 are typically addressed separately. However, unlike previous studies, this research presents an integrated process model that combines these elements in a unified framework. Furthermore, the identification of critical points within the proposed process and the assessment of their relative importance represent a significant contribution to the originality and practical value of this study.

In terms of the functioning of quality circles and their problem-solving methodology, the systematic approach consists of the following steps: identifying the problem, conducting root-cause analysis, prioritizing the causes, developing solutions, and presenting them to top management. Within the scope of this paper, the term "application of circle activity" refers to the entire problem-solving methodology

Figure 1 depicts proposed process which was generated by supporting with quality circles and PDCA cycle of ISO 45001:2018.

As ISO 45001:2018 is an international management system standard designed to enhance occupational health and safety by preventing work-related accidents and illnesses through a risk-based approach and active employee participation [25], this extension utilizes tools related to quality circles to further improve the ISO approach, simultaneously enhancing both employee involvement and system efficiency.

The planning section begins with the selection of circle leaders and the formation of workgroups with OHS professionals. The selection of circle leaders is crucial because the appropriate choice of leaders significantly impacts the success of nearly the entire process. At this point, as a scientific approach, determining the selection criteria and applying an MCDM process may be useful in selecting the most suitable circle leaders from the available alternatives. The selection of suitable circle leaders can contribute to the sustainability of the entire process. Especially considering that the selected leaders and team members will generate OHS instructions based on ISO 45001:2018 by conducting shared studies, the leader selection becomes a critical step in the process. This stage can be defined as the point where instructions based on the ISO 45001:2018 OHS management system are determined. On the other hand, educational activities, particularly those focused on basic OHS rules and applications, specific problem-solving methodologies, and OHS management systems, are conducted during the planning stage. Training for both white- and blue-collar employees on nearly all OHS-related issues was included as a crucial part of the planning section, in addition to the training of circle leaders. Clearly, to maintain sustainability and employee involvement, educational activities on problem-solving techniques play a vital role in the planning section. Quality circle approaches are entirely dependent on employees' voluntary participation. Therefore, the selection of circle members takes place during the planning section. However, to achieve the overall success of the process, it is essential not only to select volunteer staff but also to ensure that the selected staff are qualified. As Yılmaz Kaya and Dağdeviren [26] noted, the appropriate distribution of a company's resources or capacity optimizes organizational goals and helps achieve strategic targets.

The second stage of the proposed process is the "Do" step. At this stage, after the OHS and problem-solving training are provided, the proposed ISO 45001:2018 guidelines and instructions are re-examined. If necessary, the instructions can be updated. Circle activities, which aim to solve and eliminate problems through root-cause analysis, are implemented at this stage. In the "Do" step, the implementation of circle activities gives managers the opportunity to assess whether the generated instructions and guidelines align with the company's overall goals. Thus, after reviewing the guidelines and applying the circle activity, top management can refine the guidelines, which play a critical role in ensuring the sustainability of the OHS process.

The third stage is the "Check" stage. At this stage, almost all outputs produced and proposed by the circle are reviewed, and the results and solution proposals are reported to top management. This step is the phase where the most significant feedback is received among the successive stages of the system in sustainability studies. As a result, businesses, managers, and team leaders can identify deficiencies and make efforts to address them. A holistic evaluation can be conducted in terms of the process's success by comparing it with previous periods, particularly regarding the performance criteria established for the process. Parameters such as the number of work accident-free days, the number of diagnosed occupational diseases, or the number of near misses can be set as performance criteria. In addition to the performance criteria of the ISO 45001:2018 standard, the number of studies conducted within the quality circle, the number of errors detected in team meetings, and statistical data showing whether the circle activities are effective or not can also be included in the performance criteria. This approach helps establish a feedback system and take steps toward a sustainable business. To some extent, this forms the foundation for continuous improvement. When evaluated from this perspective, combining quality circles with ISO 45001 provides businesses with an important opportunity to ensure continuous improvement and sustainability in terms of OHS activities' operability and performance.

The final stage is the "Act" stage. This stage is carried out according to the results of the "Check" stage. In the "Check" stage, the results of circle activities are presented objectively. This means that top management has the opportunity to carefully examine both the positive and negative situations. Negative situations, mistakes, and near-miss events represent opportunities for improvement. At this stage, OHS measures developed in connection with circle activities are planned and implemented. A key aspect of all management processes is identifying opportunities for improvement. Once the problem is identified, determining the measures to address it becomes a more manageable task. Therefore, in the "Act" stage, corrective actions are planned and taken. Similar to checking the results of circle activities, the results and effectiveness of the measures taken need to be regularly monitored.

3. MATERIALS AND METHODS

Since the PDCA cycle and its sub-factors were expressed in a hierarchical structure (see Figures 1 and 2), the weights of these factors were calculated using the Analytical Hierarchy Process (AHP) technique. The AHP technique, developed by Saaty [27], is used to solve complex decision-making problems. Since its development, AHP has been applied to decision problems in various research domains, including construction [28], green energy [29], ergonomic design and occupational health and safety [30,31,32], management [33], education [34], aviation [35], and OHS [36], among others. Additionally, the process involves uncertainty, as quality circles have not yet been implemented in businesses within the scope of ISO 45001. For this reason, calculations were made using the fuzzy extension of AHP.

3.1. Spherical Fuzzy Sets and Spherical Fuzzy Extension of AHP

Kutlu Gündoğdu and Kahraman, by combining Pythagorean and Neutrosophic fuzzy sets, introduced the concept of Spherical Fuzzy Sets (SFSs) to the fuzzy logic literature [37]. These sets play a significant role in helping decision-makers gain a more comprehensive understanding of decision-making processes by focusing on their degrees of hesitation, thereby facilitating more informed and balanced decisions [4, 37, 38, 39]. SFSs are particularly useful in solving complex decision problems where uncertainty and ambiguity are prevalent, offering decision-makers a broader perspective and contributing significantly to the resolution of such challenges [37-39].

SFS has membership, non-membership, and hesitancy degrees, just like Pythagorean fuzzy sets [37-40]. Let E_1 and E_2 be two universes. Let $\tilde{A}_s$, and $\tilde{B}_s$ of the universe of discourse E_1 and E_2 be as follows

$$\tilde{A}_s = \{x, (\mu_{\tilde{A}_s}(x), v_{\tilde{A}_s}(x), \pi_{\tilde{A}_s}(x)) \mid x \in E_1\}$$

where

$$\mu_{\tilde{A}_s}(x): \mathrm{E}_1 \to [0,1], v_{\tilde{A}_s}(x): \mathrm{E}_1 \to [0,1], \pi_{\tilde{A}_s}(x): \mathrm{E}_1 \to [0,1]$$

and

$$0 \le \mu^2_{\tilde{A}_s}(x) + v^2_{\tilde{A}_s}(x) + \pi^2_{\tilde{A}_s}(x) \le 1 \qquad \forall x \in E_1$$

For each *x*, $\mu_{\tilde{A}_s}(x)$, $v_{\tilde{A}_s}(x)$, $\pi_{\tilde{A}_s}(x)$ represents the membership function, the non-membership function, and the hesitancy degree, respectively.

Similarly, $\tilde{B}_s = \{y, (\mu_{\tilde{A}_s}(y), v_{\tilde{A}_s}(y), \pi_{\tilde{A}_s}(y)) \mid y \in E_2\}$

where

$$\mu_{\tilde{B}_s}(y): \mathrm{E}_2 \to [0,1], v_{\tilde{B}_s}(y): \mathrm{E}_2 \to [0,1], \pi_{\tilde{B}_s}(y): \mathrm{E}_2 \to [0,1]$$

and

$$0 \le \mu^2_{\tilde{B}_s}(y) + v^2_{\tilde{B}_s}(y) + \pi^2_{\tilde{B}_s}(y) \le 1 \qquad \forall y \in E_2$$

For each *y*, $\mu_{\tilde{B}_s}(y)$, $v_{\tilde{B}_s}(y)$, $\pi_{\tilde{B}_s}(y)$ represents the membership function, the non-membership function, and the hesitancy degree, respectively [37]. The basic arithmetical operations for the SFS were developed by Kutlu Gündoğdu and Kahraman [37, 38]. The following formula can be utilized for the summation of two SFS:

$$\tilde{A}_s \oplus \tilde{B}_s = \{(\mu^2_{\tilde{A}_s} + \mu^2_{\tilde{B}_s} - \mu^2_{\tilde{A}_s}\mu^2_{\tilde{B}_s})^{1/2}, v_{\tilde{A}_s}v_{\tilde{B}_s}, ((1-\mu^2_{\tilde{B}_s})\pi^2_{\tilde{A}_s} + (1-\mu^2_{\tilde{A}_s})\pi^2_{\tilde{B}_s} - \pi^2_{\tilde{A}_s}\pi^2_{\tilde{B}_s})^{1/2}\}$$

The following formula is offered for the multiplication of two SFS:

$$\tilde{A}_s \otimes \tilde{B}_s = \{\mu_{\tilde{A}_s}\mu_{\tilde{B}_s}, (v^2_{\tilde{A}_s} + v^2_{\tilde{B}_s} - v^2_{\tilde{A}_s}v^2_{\tilde{B}_s})^{1/2}, ((1-v^2_{\tilde{B}_s})\pi^2_{\tilde{A}_s} + (1-v^2_{\tilde{A}_s})\pi^2_{\tilde{B}_s} - \pi^2_{\tilde{A}_s}\pi^2_{\tilde{B}_s})^{1/2}\}$$

For the multiplication of an SFS by scalar k *(k>0)*, the following formula is used:

$$k * \tilde{A}_s = \{(1-(1-\mu^2_{\tilde{A}_s})^k)^{1/2}, v^k_{\tilde{A}_s}, ((1-\mu^2_{\tilde{A}_s})^k - (1-\mu^2_{\tilde{A}_s} - \pi^2_{\tilde{A}_s})^k)^{1/2}\}$$

3.2. Calculation process of SF-AHP

In decision-making problems, it is essential to identify the criteria and sub-criteria that will influence the decision. However, in this study, a direct choice problem is not addressed; therefore, alternatives are not included. The technique employed in this study is intended to analyze the critical factors of the process in the context of extending ISO 45001:2018. As with any decision-making approach, the boundaries of the decision problem (decision hierarchy) should be established at the outset [41-43]. Subsequently, an expert or group of experts is asked to evaluate the criteria, including any sub-criteria, but without considering alternatives [34, 43-45]. In the SF-AHP technique, these evaluations are conducted by utilizing the scale given in Table 1 [37].

Table 1. The utilized linguistic scale [37]

Linguistic Expressions	μ, v, π	Score Index (SI)
Absolutely more importance (AMI)	(0.90,1.0,0.0)	9
Very high importance (VHI)	(0.8,0.2,0.1)	7
High importance (HI)	(0.7,0.3,0.2)	5
Slightly more importance (SMI)	(0.6,0.4,0.3)	3
Equally importance (EI)	(0.5,0.4,0.4)	1
Slightly low importance (SLI)	(0.4,0.6,0.3)	1/3
Low importance (LI)	(0.3,0.7,0.2)	1/5
Very low importance (VLI)	(0.2,0.8,0.1)	1/7
Absolutely low importance (ALI)	(0.1,0.9,0.0)	1/9

The scoring index is essential for evaluating the consistency ratio of pairwise comparison matrices, especially when using the conventional calculation method. To compute the score index for the linguistic expressions of AMI, VHI, HI, and SMI, the following equation is employed.

$$SI = \sqrt{\left| 100 * \left[(\mu_{\tilde{A}_s} - \pi_{\tilde{A}_s})^2 - (v_{\tilde{A}_s} - \pi_{\tilde{A}_s})^2 \right] \right|} \quad (1)$$

To calculate the score index of ALI, VLI, LI, SLI the following equation is utilized.

$$\frac{1}{SI} = \frac{1}{\sqrt{\left| 100 * \left[(\mu_{\tilde{A}_s} - \pi_{\tilde{A}_s})^2 - (v_{\tilde{A}_s} - \pi_{\tilde{A}_s})^2 \right] \right|}} \quad (2)$$

After obtaining the score index for each element in the pairwise comparison matrices, the traditional consistency calculation steps must be applied. The acceptable highest value for the consistency ratio is 10% [46]. The fuzzy weights of the criteria, sub-criteria, and alternatives are generated after testing and ensuring that the entire pairwise comparison matrix is consistent. This procedure uses the Spherical Weighted Arithmetic Mean (SWAM) operator.

$$SWAM_w(A_{S1},....,A_{Sn}) = w_1 A_{S1} + w_2 A_{S2} + ... + w_n A_{Sn}$$
$$= \left\langle \left[1 - \prod_{i=1}^{n} (1 - \mu^2_{\tilde{A}_{si}})^{w_i} \right]^{1/2}, \prod_{i=1}^{n} v_{\tilde{A}_{si}}^{w_i}, \left[\prod_{i=1}^{n} (1 - \mu^2_{\tilde{A}_{si}})^{w_i} - \prod_{i=1}^{n} (1 - \mu^2_{\tilde{A}_{si}} - \pi^2_{\tilde{A}_{si}})^{w_i} \right]^{1/2} \right\rangle \quad (3)$$

where *w=1/n.*

After that, the global weights of the main criteria need to be defuzzified with the help of the following equation.

$$S(\tilde{w}_j^s) = \sqrt{\left| 100 * \left[(3\mu_{\tilde{A}_s} - \frac{\pi_{\tilde{A}_s}}{2})^2 - (\frac{v_{\tilde{A}_s}}{2} - \pi_{\tilde{A}_s})^2 \right] \right|} \quad (4)$$

The calculated crisp weights are normalized by utilizing the following equation.

$$\bar{w}_j^s = \frac{S(\tilde{w}_j^s)}{\sum_{j=1}^{n} S(\tilde{w}_j^s)} \quad (5)$$

4. DETERMINING AND WEIGHTING THE KEY POINT OF THE QUALITY CIRCLES WITH ISO 45001:2018

To analyze the process obtained by expanding ISO 45001:2018 with quality circles, as outlined in the second section, and to provide better insights to strategic decision-makers, critical points are identified and prioritized in this section. As shown in Figure 1, there are essentially four steps identified to extend ISO 45001:2018 with quality circles. Moreover, each step includes specific tasks that need to be accomplished. For each step, the key points are determined and illustrated in Figure 2. For example, in the planning step, there are four key points

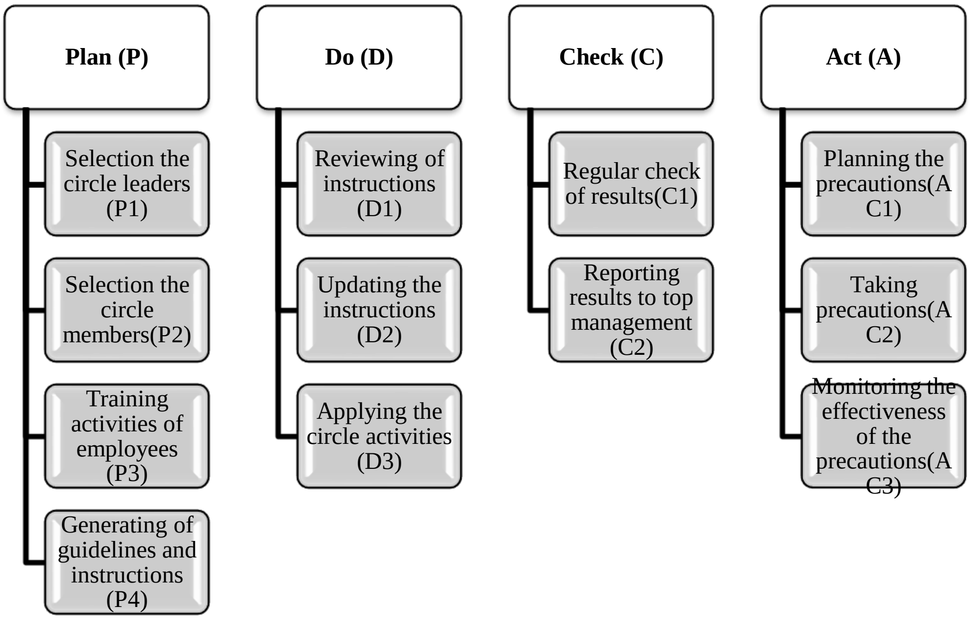

Figure 2. The determined key points of the proposed approach

After determining the key points of each step, we can now compute the relative weights of these key points. The calculation procedure, explained in Section 3, begins with conducting pairwise comparisons. Table 2 shows the pairwise comparisons for the key points of the planning step. By following the employed calculation process, the weights for each key point were computed. Expert evaluations were conducted using the scale provided in Table 1.

Table 2. Pairwise comparisons for the key points of the "plan step" and their calculated weights

	P1	P2	P3	P4	Weights
P1	EE	SMI	HI	VHI	0.34
P2	SLI	EE	SMI	SMI	0.26
P3	LI	SLI	EE	SLI	0.19
P4	VLI	SLI	SMI	EE	0.22

CR:0.09

The abbreviation "CR" stands for consistency ratio. The acceptable limit for CR is 10%, or 0.1 [46]. The CRs of the conducted pairwise evaluations were all lower than 0.1, indicating that the determined weights are valid. According to Table 2, the selection of the circle leader is the most important key factor in the planning step. Table 3 presents the pairwise comparisons for the key points of the "do" step and their calculated weights. According to Table 3, among the key points of the "do" step, D1 (i.e., reviewing of instructions) is determined to be the most important key point.

Table 3. Pairwise comparisons for the key points of "do step" and their calculated weights

	D1	D2	D3	Weights
D1	EI	VHI	SMI	0.43
D2	VLI	EI	LI	0.22
D3	SLI	HI	EI	0.35

CR:0.05

Table 4 shows the pairwise comparisons for the key points of the "control" step .There are two key points for the control step, and the first one is by far the most critical according to their importance weights.

Table 4. Pairwise comparisons for the key points of "control step" and their calculated weights

	C1	C2	Weights
C1	EI	HI	0.61
C2	LI	EI	0.39

Table 5 indicates the pairwise comparisons for the act step's key points. Accordingly, the most critical key point of the act step is specified as planning the precautions.

Table 5. Pairwise comparisons for the key points of the "act step" and their calculated weights

	AC1	AC2	AC3	Weights
AC1	EI	HI	SMI	0.41
AC2	LI	EI	SLI	0.26
AC3	SLI	SMI	EI	0.33

CR=0.03

Thus, the weights of all sub-factors have been calculated. However, it is not possible to evaluate these sub-factor weights together at this stage. More specifically, at this stage, the calculated weights are all local, and they need to be converted into global weights. For this process, it is necessary to weigh the main stages relative to each other and establish a relationship between these weights.

Table 6 shows the evaluations and weights for the main stages. According to these evaluations, the most critical main stage was determined to be the "Plan" stage.

Table 6. Pairwise comparisons for the main steps and their calculated weights

	P	D	C	A	Weights
P	EE	SMI	HI	HI	0.32
D	SLI	EE	SMI	SMI	0.26
C	LI	SLI	EE	SMI	0.23
A	LI	SLI	SLI	EE	0.19

Cr:0.07

Table 7 indicates the local and global weights of all the determined key points. To calculate the global weights, the main factor weights need to be multiplied by the local weights. The summation of the global weights must equal 1. Thus, we can analyze and interpret the global weights within a reasonable context.

Table 7. Local and global weights of all determined key points

Main keys	**Sub Keys**	**Local Weights**	**Global Weights**
Plan	*0.32*		
	Selection of the circle leaders	0.34	0.108
	Selection of the circle members	0.26	0.082
	Training activities of employees	0.19	0.061
	Generating guidelines and instructions	0.22	0.070
Do	*0.26*		
	Reviewing of instructions	0.43	0.112
	Updating the instructions	0.22	0.057
	Applying the circle activities	0.35	0.091
Check	*0.23*		
	Regular check of results	0.61	0.140
	Reporting results to top management	0.39	0.090
Act	*0.19*		
	Planning the precautions	0.41	0.078
	Taking precautions	0.26	0.049
	Monitoring the effectiveness of the precautions	0.33	0.063

To better understand the structure of the proposed approach, the global weights of sub-factors need to be analyzed as well as the local weights. The meaning of the global weights here is that it shows the place of the relevant key factor in the whole. According to the results, control and feedback mechanisms are the most effective factors in ensuring the sustainability of the system, as supported by comprehensive explanations. Moreover, the sub-step “Regular check of results” has the highest global weight, clearly showing that regular monitoring plays a key role in the system’s success. The most important main stage is the “Plan” stage. In this stage, steps such as the “Selection of the circle leaders” and the “Selection of the circle members” come to the forefront. The proper selection of leaders and members is critical for the effectiveness of the subsequent stages of the process. In particular, the high weight assigned to leader selection emphasizes the decisive role of leaders in problem-solving and process management. The “Do” stage also makes a significant contribution. Within this group, “Reviewing of instructions” has been identified as the most effective sub-step, highlighting that the relevance and currency of procedures are fundamental to successful implementation.

“Applying the circle activities” is also a highly effective step, which can be interpreted as a finding that supports employee participation and the practical application of the process in the field.

The “Act” stage has the lowest overall weight, but this does not imply it is unimportant. On the contrary, sub-steps such as “Planning the precautions” and “Monitoring the effectiveness of the precautions” are essential for evaluating whether the measures taken are effective.

In a management process, control activities and feedback mechanisms can be considered fundamental components for ensuring the long-term sustainability and continuous improvement of the system. Our findings reveal that regular monitoring and evaluation of quality circle activities emerge as the most critical success factors, emphasizing the necessity of consistent auditing to maintain alignment with corporate goals. Following closely in importance are the regular review of procedural instructions and the strategic selection of circle leaders. The role of circle leaders extends beyond mere coordination; they play a significant part in directing the problem-solving process, facilitating team discussions, and implementing appropriate methodologies to generate practical solutions. Their ability to identify root causes and mobilize team efforts directly impacts the effectiveness of quality circles.

When these results are interpreted within a broader management context, it becomes evident that control-related elements are particularly influential in guiding the system toward success. Although management systems generally emphasize compliance with established rules and frameworks, the actual impact of each rule or procedure on performance outcomes can only be accurately assessed through long-term monitoring and evaluation. This study addresses that gap by presenting a new, integrated process model that combines ISO 45001:2018 with quality circles, offering not only a conceptual framework but also empirical insights into which components carry the greatest strategic importance. By applying an analytical method to determine the relative importance of the identified critical points, the study provides a data-driven prioritization tool for practitioners. As presented in Table 7, this tool enables organizations to make informed decisions about where to allocate resources and direct their attention. For instance, while the selection of circle leaders typically falls under the responsibility of top management, the implementation and reporting of circle activities depend more heavily on the engagement and collaboration of operational-level employees. This dual structure highlights the systemic nature of the proposed model, which transcends hierarchical boundaries and fosters cross-level collaboration.

Furthermore, the study demonstrates that the proposed approach not only serves a technical purpose but also reflects a holistic management philosophy. It aligns with core principles such as sustainability, employee engagement, human-centered design, and leadership commitment. The emphasis on factors involving both strategic decision-makers and frontline employees points to a deliberate and inclusive design that encourages a culture of shared responsibility. Ultimately, the findings confirm that for OHS management systems to be truly effective, they must be grounded in a participatory framework that reinforces both top-down control and bottom-up involvement.

5.DISCUSSION AND CONCLUSION

Basically, almost all studies on OHS aim to provide managers with suggestions related to strategic management and the sustainability of human resources, ultimately reducing health costs, eliminating work accidents, and preventing occupational diseases. To achieve this outcome—reaching a singular truth—various approaches can be pursued. The current study proposes a solution by integrating ISO 45001:2018, based on the PDCA cycle, with quality circles. It is believed that incorporating the extension of quality circles will contribute significantly to the successful implementation of ISO 45001:2018 and ensure its continued application beyond just a theoretical framework. Transforming the distinct application steps of ISO 45001:2018 into a comprehensive problem-solving technique through group collaboration is the primary contribution of this study to the literature. Almost every stage of the proposed approach emphasizes sustainability. As a result, both worker participation and the safety culture, which ISO 45001:2018 aims to instill, are spread throughout the organization.

On the other hand, determining which process step to prioritize for rapid and safe success, and using an analytical technique for this determination, can be seen as a secondary contribution of this paper. Additionally, this calculation technique takes into account the uncertainty inherent in the process. One of the critical factors in achieving sustainable development is ensuring that strategic management and its subcomponents are sustainable. It is not enough to define sustainability simply as controlling the results of certain processes. Demonstrating continuous improvement through incremental steps is a crucial aspect of sustainability. This concept, often referred to as sustainable development, is supported by the sustainability of human resource-related parameters, especially in human-driven production companies. Therefore, this study is closely linked to sustainable development, as it outlines a comprehensive process for ensuring the well-being of human resources in the production environment and making it sustainable.

However, as with any framework involving radical change across a factory or organization, certain challenges must be acknowledged. In particular, in traditional workplaces where hierarchical structures are dominant, employee resistance may contribute to reluctance toward changes in business practices, thereby hindering the effectiveness of quality circles. In addition, the proposed changes require the allocation of specific resources. Resource constraints such as limited time, financial investment, or the expertise needed to carry out group-based problem-solving activities may affect the practical application of the proposed method. Furthermore, the proposed process must be systematically advanced. Sustainability, continuous improvement, ongoing process monitoring, and taking action based on control results all require the participation and support of all employees, including top management and all levels of leadership. To overcome this challenge, comprehensive training should be provided to both employees and managers throughout the organization. These are important challenges that must be taken into account when implementing the proposed process full-time in real production environments.

Nevertheless, additional efforts can certainly be made to overcome these challenges and operationalize the proposed process. More specifically, measures such as targeted training programs and gradual transitions to the new approach can help employees build trust in the process and recognize its benefits, thus reducing resistance. Future studies may need to address these limitations by proposing mitigation strategies such as change management training, phased implementation, or incentive mechanisms to enhance employee participation.

This study is a first in the literature in many respects, with the expansion of ISO 45001:2018, the proposal of a new process based on this, and the calculation of the critical points of this process. For further studies, lean production techniques such as 5S and Poka Yoke, which are suggested in terms of health and safety management, can be used in the field of OHS, and simplification applications can be made in accordance with the ISO 45001:2018 standard. For the next stage, a process proposal for simultaneous use of simplification and quality circles can also be made. Moreover, by including quality circles expanded with Kaizen approaches in ISO 45001:2018 processes, the scope of employee participation and sustainability concepts can be expanded based on OHS. Moreover, in the evolution of total quality management over time, it is evident that the impact of artificial intelligence and Industry 4.0 has become more prominent in recent years [47]. Based on this, future studies may explore the expansion of ISO 45001 with new approaches in TQM, such as green quality circles and sustainable development goals

This study provides a theoretical contribution to the literature. If the proposed process is successfully implemented in a production environment where a certain level of professionalism has been achieved in the application of ISO 45001:2018, the theoretical and practical contributions can be clearly demonstrated. The calculations conducted in this study were made for situations where the decision-making environment involves uncertainty or fuzziness. Since quality circles, which have been introduced as an extension to the ISO 45001:2018 framework, have not yet been implemented in enterprises, it is logical to approach these calculations from an uncertainty/fuzzy perspective, as done in this paper. In future studies, as the use of quality circles in OHS management systems increases and the proposed process is implemented, calculations can be performed in a more certain environment.

When viewed from a broader perspective, this paper, which aims to protect human resources from OHS-related risks in the production environment and make this protection sustainable through various applications, can be further expanded by integrating green management approaches. This would enable organizations to fulfill their environmental responsibilities and safeguard human resources not only within the production environment but also outside of it.

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Aylin ADEM: contributed to topic selection, scientific publication research, determination of methods, creation of data sets, application of methods, analysis of results, creation of the article, design of the article;

Burcu YILMAZ KAYA: contributed to scientific publication research, design of the article, creation of the article;

Metin DAĞDEVİREN: contributed to the management of the study, topic selection, design of the article and proofreading and supervision.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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